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THE
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THE PSYCHOLOGY OF TASTE AND SMELL

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The reviewer, who in her last report (1929) was unduly bent upon economizing space, now means unblushingly to include in the present account several contributions which should have been discussed three years ago.

Olfactory Qualities.—A certain introspective study of olfaction, which issued from a physiological laboratory in 1927, has never as yet received the attention it deserves. Here we have an elaborate study of the conscious process of smelling, the first ever to be made (to the knowledge of the reviewer) by a writer obviously under the influence of the *Gestalt* movement. The writer is Achelis (1). The nucleus of the study consists in the introspective reports of eight subjects who were required to smell eleven different scents (chosen for their sensory distinctness) and to report their experience as it developed from moment to moment. The time of smelling was not rigidly limited and the only instruction which the subjects received was to the effect that anything which they might say would be of interest to the experimenter ("alles gilt"). Achelis makes some noteworthy remarks upon the choice and care of scents but he gives few details about his own experimental procedure. One may, however, infer from the reports of introspection that each observer dealt with each scent several times.

The purpose of Achelis was to study odor experience not only in a genetic fashion but also in its relation to the whole of consciousness from moment to moment. He concludes that there are six stages in the apprehension of an odor, namely: (1) The motor stage of approach or withdrawal (the "Neigung" phase), in which the smell

attacks the subject; (2) a stage in which the subject detaches himself from the odor; (3) a stage in which the odor comes back as a distinct impression; (4) a stage of "I-in-a-situation," in which the odor becomes more distinct and in which the stimulus-object is visualized and the odor is said to smell like some object of past experience (as, *e.g.,* a collection of beetles); (5) a stage in which the subject feels toward the stimulus-object ("das Ding") as one feels toward the smell (the rose-fragrance is the rose); (6) a stage in which the smell appears as a complex quality with various aspects or "Dimensionen." Achelis acknowledges an indebtedness to Hermann (in Krueger's *Neue Psychologische Studien,* 1926) for the groundwork of this delineation but he has elaborated upon Hermann's distinctions. The brief time ordinarily allowed to a subject for observing his experience with an odor is, in the opinion of Achelis, one chief cause of the disagreement which is rife in regard to the odor qualities.

However, this writer does not concern himself with the number and interrelations of what most of us would call smell qualities proper. His interest is focussed on the complexity of the concrete experience aroused by a smell stimulus and, in particular, upon the "Dimensionen" (secondary variables?) of odors. These are three in number—"Räumlichkeit" (volume or spatial nature), "Gliederung" (composition, structure, configuration), and "Bindung" (subjective appropriation by the subject). Each of these characters (he says) varies in degree and varies independently of both the others. Characters of "Räumlichkeit" are denoted by touch words such as soft, hard, round, and angular. (The smell of oil of rose is soft and round and one penetrates into it. The odor of oil of pine needles is angular and hard.) Characters of "Gliederung" are expressed in terms of harmony. (A smell, for example, may be dissonant, or it may have figure and ground—"Schärfe" and "Hintergrund.") In "Bindung," smells are like tastes. They have not that independence of the observer which belongs to a complete *Gestalt.* These affirmations are based (at least ostensibly) upon the introspective reports of the subjects of Achelis—reports which he quotes with commendable fullness. He stresses the fact that the descriptions of the subjects depended much upon the attitude ("Verhalten") which each individual took to each odor.

His final chapter is concerned with the comparison of smell with the other senses. He says that it is the subjectivity of smell—*i.e.,* the fact that there are no objective or "free" odor-forms—which makes it impossible to have an art which would correspond to smell

as music corresponds to hearing. It is also the subjectivity of smell which renders it necessary to borrow descriptive terms which properly belong to vision, hearing, and touch. (So says Achelis, but certainly such borrowing is not confined to the description of odors. What of "brightness" in tones and in pressures?)

Another important and a more recent study of smell-qualities is Hazzard's (15). To the reviewer it seems as if the work of Hazzard and Achelis must have been strongly affected by a common influence. The method of both was "phenomenological"—the method of simple description. Hazzard's subjects, to whom fourteen different scents were repeatedly presented, were instructed merely to "describe the course" of their experience. Hazzard's "texture"—although the term is Titchenerian—is the counterpart of the Räumlichkeit of Achelis and plays a conspicuous rôle in the reports of the observers. Both stress the effect of attitude or set upon the descriptions given. Nevertheless, the study of Hazzard is by no means an offshoot of that of Achelis, to whom she does not refer. Her primary purpose was to obtain evidence for or against the classification of Henning. Her scents were so chosen as to constitute a sort of "skeleton" of Henning's prism. The exposure time was for the most part three seconds only and in no case exceeded five. She had six subjects, of whom the two best trained were herself and Hoisington. Except in the case of three substances (cedar wood, apiol, and oil of cinnamon bark), Hazzard's results fit pretty well into the pattern of Henning's prism. It is certainly noteworthy that an experimenter who has followed Henning's own chief method should secure results much more consonant with his than are any which have been secured by the methods of rank-order or of paired-comparison. But it is also to be noted that knowledge of the classification and the terminology of Henning may itself have produced a strong set in several of Hazzard's subjects—especially strong in the two best trained.

The Olfactory Stimulus.—In the field in which physics, chemistry, and psychology overlap, the study which Ouchakov (23) has made of smell absorption seems to the reviewer to be of great importance. This investigator saturated the air enclosed in one-liter bottles with various scents. Each odorous substance was allowed to remain in the bottom of the bottle for two or three hours. Then a piece of the substance whose absorbing power was to be tested was suspended in the bottle by a thread and the stopper was replaced. The substance hung in the scented air for a "determined time." It was then removed and was protected from contamination by other odors. At

intervals it was tested for odor, and the length of time for which it retained the smell to which it had been exposed was regarded as the measure of its absorbing power for that particular scent. Among Ouchakov's many conclusions the following are outstanding: (1) The greater the molecular weight of a scent, the longer it remains in the absorber. (2) The greater the amplitude of the surface of the absorbing substance—in other words, the rougher or the more porous it is—the greater its absorbing power. For this reason, bone-charcoal is peculiarly absorbent. (3) Some substances are especially absorbent in relation to certain scents. Thus, bone-charcoal will retain the odor of vanillin a remarkably long time. The substances which Ouchakov tested as absorbers were bone-charcoal, cork, hair, broadcloth, gauze, absorbent cotton, rubber, filter-paper, cotton cloth, glass. He used eleven different scents, which it seems unnecessary to list here. Ouchakov should be read in detail by anyone who is actually working with scents.

Little new apparatus for the study either of smell or of taste has been reported in the last three years. Saxe (**26**), however, proposes a combination of flasks, an air pump, and a manometer by which the rate of the odorous air-current and the density of the odorous gas can be kept constant and accurately measured.

Smell Localization.—Hambloch and Püschel (**14**) have demonstrated that traces of a scent can be localized much better if one interpolates a long and slender glass tube between one's nose and the surface over which one is searching than if one applies one's nose directly to the surface. With the tube, moreover, one can differentiate between the traces of two different scents which are so near together that they fuse if the nose is directly applied to the surface to be examined.

The Pleasantness and Unpleasantness of Odors.—In the last few years, more work has been done on the affective aspect of smells than upon any other feature of olfaction. Beebe-Center (**4**) and Young (**31**) have demonstrated by different methods the constancy of affective judgments. Beebe-Center used fourteen scents and eight observers, who were three times required to arrange the scents in order from the most pleasant to the most unpleasant. Between the first and second of these rankings an interval of a few days elapsed but between the second and third the interval amounted to weeks or months. Beebe-Center calculated rank-order coefficients (1) to show the degree of agreement between the various observers in regard to the affective character of the several smells and (2) to show the

degree to which each individual observer agreed with himself in the three trials. The constancy of the subjects proved distinctly greater than their unanimity.

In one of his studies in affective psychology, Young has used scents in trying out the "scale of values method." His subjects were nineteen in number and his stimulus-object included thirty-two scents and an empty bottle. The observers were instructed to express an absolute judgment upon each odor in terms of a scale which ranged through five degrees of pleasantness, through indifference, and then through five degrees of unpleasantness. In the main portion of the experiments, each observer judged the odors only once. The results appear in a frequency table which shows the number of times each odor was rated in a particular way. Two of the subjects judged the odors for twelve successive days. A certain statistical constancy is evident both in the judgments of individual odors by different subjects and in the series of judgments made by those observers who rated the smells a dozen times. Young fully realizes that in many of the judgments actual feelings of pleasantness and unpleasantness were probably absent.

Frank and Ludvigh (12) have investigated the retroactive effect of pleasant and unpleasant odors on learning. Series of nonsense syllables were partially learned and mastery finally tested by the method of right associates (*Treffermethode*). But directly after the presentation of each series the subject was required to determine the relative affective value of six smells by the method of paired-comparison. Ten minutes after this latter task was accomplished, the memory test was made. In one case out of every four, the smells were pleasant, in one case they were unpleasant, and in two cases indifferent. It was actually found that recall was better after the pleasant than after the indifferent smells, and better after the indifferent than after the unpleasant. The subjects were fifteen university students.

Later, Frank (11) attempted to reduce the pleasantness and unpleasantness of certain odor stimuli by utilizing the "principle of affective equilibrium." Details of his complicated procedure cannot be given here. Frank finally concluded that smells which are normally pleasant or unpleasant have in virtue of their own sensory quality a certain effect upon retention even after their pleasantness or unpleasantness has been minimized.

Both Beebe-Center (3) and Kniep, Morgan and Young (18) have contributed evidence for a law of affective equilibrium or at least for

affective contrast in the realm of odors. Space will not permit the reviewer to make clear the experimental procedure of Beebe-Center. In brief, he found that when his subjects had dealt with a number of unpleasant smells by the method of paired-comparison and were then required to make absolute judgments upon these same or other unpleasant smells, their appraisals of unpleasantness had become very moderate. The case was analogous when the odors were pleasant. Kniep, Morgan and Young, working with one hundred student observers and series in which the same three pleasant followed the same three unpleasant smells or *vice versa,* showed clearly that there is such a phenomenon as affective contrast but that it is more marked when unpleasant smells follow pleasant than it is when the case is reversed. However, their results also show decisively that an odor has an affective value of its own, a value in part independent of context. Yet the empty bottle, which was the last member of every series, was more often reported as pleasant than as unpleasant even when it was immediately preceded by pleasant scents.

The same investigators have also shown that, in spite of some difference in attitude, there is little divergence between the affective judgments of children from seven through nine years of age, of children from eleven through thirteen years of age, and of university students.

Wells (29) has measured the affective reaction-time for odors, that is, the period which elapses between the beginning of the first inhalation and the moment when the subject indicates his affective judgment. In the first set of experiments, in which he used a kymograph, he found that a judgment of pleasant or unpleasant involved a reaction-time of .88 seconds. In a second set, in which the kymograph was replaced by a chronoscope, he obtained an average time of 555σ. In a second set of chronoscope experiments, a set in which an empty bottle was introduced among the scent bottles and in which the subjects had to judge the stimulus object as affective or indifferent, the average reaction time proved to be 615σ.

The Pleasantness and Unpleasantness of Tastes.—In the realm of tastes, Engel (10) has furnished some experimental verification of the common teaching that weak sensations are ordinarily indifferent, sensations of moderate intensity pleasant, and very intense sensations unpleasant. He worked with solutions of cane sugar, cooking salt, tartaric acid, and sulphate of quinine. The observer was given 10 cc. of liquid at a dose. Engel points out three important reservations which should be made in applying the familiar law to tastes: (1)

There are two zones of indifference. Not only are weak tastes indifferent but so also are certain strong tastes which stand on the borderline between pleasant and unpleasant. (2) Unless the stimulation is protracted, the most intense sweetness is pleasant. (3) The salt, the sour and the bitter at an intensity which removes them as far as possible from the region of constant unpleasantness are not pronounced pleasant in 100 per cent. of absolute judgments. (The percentages of pleasantness judgments were respectively 66, 54 and 24.)

Taste Mixture and Compensation.—Hambloch and Püschel (13) have made an experimental study of mixture in varying concentrations of each pair of the principal tastes. They used the same substances as did Engel except that they substituted hydrochloride for sulphate of quinine and in all cases the stimulus consisted of 10 c.c. of sapid solution. Although their findings apply to every pair of tastes, yet the reviewer, for the sake of concreteness, will speak only of salt and bitter. In one series for each subject the concentration of the salt solution was increased while that of the bitter was decreased, and in a parallel series the bitter was increased while the salt was decreased. The experimenters distinguish these five perceptual zones: (1) a zone in which the salt is completely masked by the bitter; (2) a zone in which the salt is not tasted as salt and yet makes the bitter taste unlike a pure bitter; (3) a zone in which either salt or bitter may be made to stand out by attention; (4) a zone which corresponds to the second zone, and (5) a zone which corresponds to the first, except that here the bitter is masked by the salt.

Adaptation to Taste Stimuli (Negative Adaptation or "Exhaustion").—Mayer (20) has carefully investigated this phenomenon, which he calls "Umstimmung." His stimuli were the following: cane sugar, grape sugar, galactose, cooking salt, hydrochloric acid, and hydrochloride of quinine. He also gave 10 cc. of sapid solution at a dose. In examining his results it is necessary to keep in mind the distinction between the stimulus which produces adaptation and the stimulus by which adaptation is measured. All results are expressed in the ratio of the threshold concentration of the test stimulus to the normal threshold concentration of the substance. By adaptation-time he means not the time necessary to produce complete adaptation but the time during which the experimenter allows the adaptation stimulus to work on the taste receptors. Mayer's results are distinctly important. They may be summarized as follows: (a) From the experiments in which the adaptation stimulus and the taste

stimulus were the same in nature (both cane sugar, for instance), the following facts emerge,—(1) As the exhaustion time increases from fifteen seconds to one minute, the degree of adaptation increases. (2) If the adaptation time exceeds two minutes, the degree of adaptation falls off. This looks as if after one minute some recovery in the receptors begins to take place even while the stimulus continues to act (p. 139 of Mayer's paper). (3) In power to produce adaptation the four tastes stand in the following order: sweet, then bitter, then salt and sour. (4) When adaptation time is constant, the degree of adaptation varies with the concentration of the solution. (b) Experiments in which the stimuli all produced sweet tastes but were chemically unlike show that the sweeter the substance is, the greater its power to produce adaptation. Thus, cane sugar is more powerful than grape sugar. (c) In the experiments in which adaptation stimulus and test stimulus produced different tastes, contrast effects appeared. Contrast, however, was not equally great nor did it even appear in every pair of tastes. Adaptation to sweet, for example, lowered in a marked degree the threshold for salt but had less effect upon that for sour and still less upon that for bitter. Bitter, on the other hand, lowered the threshold for salt and sour but raised the threshold for sweet.

Physiology and Anatomy.—Readers who are orienting themselves in the field of smell and taste should not fail to read the masterly chapter on the chemical senses in Murchison's *Foundations of Experimental Psychology.* It may be noted here (1) that the writers Parker and Crozier (**24**) take the view that in all the chemical senses, including smell, the adequate stimulus is in liquid form when it comes into contact with the sensory cells and (2) that they believe that the receptors for sweet, salt, and sour and probably for bitter are each constituted by a separate set of taste-buds. Parker (**25**), it may be mentioned, has written the article on smell and taste for the last edition of the Encyclopaedia Britannica.

Klass (**17**) has found by post-mortem examination of the brains of Bantus and certain other non-Europeans that the doubling of the striae in the olfactory tracts is not peculiar to the white race. It has been conjectured that the lateral striae are vestigial.

Smell and Taste in Animals.—Under this heading, the reviewer must confine herself to the bare indication of contributions. An excellent orientation upon the topic may be obtained from the article by von Buddenbrock-Hettersdorf (**5**) in the last edition of the Encyclopaedia Britannica. Lindley (**19**), by some clear-cut experi-

mental work, has proved beyond question that smell is more important than vision in the maze learning of the white rat. Baumann (2), who has carefully observed the behavior in captivity of some fourteen specimens of *Viper aspis* L., discusses the rôle which olfaction plays in their food-getting and reports one striking instance of conditioned response.

Wirth (30) describes apparatus which he has invented for the study of olfaction in insects. Murr (22) has made an extensive study of the fruit fly (*Habrobracon juglandis* Ashmead), which feeds upon the caterpillar of the meal worm (*Ephestia Kuehniella* Zell) and deposits its eggs in the carcass. His interest centers in the part played by olfaction in the food-finding and mating of the fruit fly and he describes, in particular, behavior which suggests a compromise between phobotaxis and osmotropotaxis. Valentine (28) has proved that in the mating of the adult meal-worm beetle olfaction is the sense chiefly concerned. Minnich (21) takes issue with McIndoo in regard to the olfactory receptors of the honey-bee. McIndoo maintains that these are to be found in the pores on the legs and wings. Minnich brings evidence to show that at least the partial integrity of the antennae is essential to olfaction. Minnich's paper, which is well worth reading, consists largely of a systematic summary of the findings of other investigators of the chemical sense in insects.

Dubreuil and Valette (7, 8, 9) have studied in the rabbit, guinea-pig and rat the distribution of small blood vessels in the sense-organs. They conclude that the venous network which surrounds circumvallate papillae, as well as touch-hairs, has a thermostatic function.

Miscellaneous Contributions.—Snyder (27) reports a case of insensitivity to the taste of certain compounds of the phenyl-thiourea group, a defect which appears to be hereditary and recessive. Henssge (16) describes a case of apparent hyperosmia, a disturbance which occurred in the first three months of pregnancy and then vanished. Daly and White (6), in a long and interesting paper, present a thorough (though not very systematic) discussion of smells as aphrodisiacs. They suggest that the usefulness of the isomers of valerianic acid in hysterical attacks may be due to the fact that the odor satisfies the patient's unconscious sex desires. They believe that scents may be aids in psychoanalysis and that the associations evoked by such odors as that of valerian should be carefully studied.

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TOUCH AND KINESTHESIS

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This review includes seventy articles which may be listed under the joint title of touch and kinesthesis. Most of them were published in the years 1930 and 1931. A number of articles which bear an earlier date of publication are included because they were not yet available when the writer submitted the last review upon this topic (this JOURNAL, 1930, 27, 298–317). These studies are classified under fifteen sub-topics (*vide infra*), according to the nature of their content or results, or their setting in this increasingly broadening field.

Excitation and discharge of sensory impulses.—Adrian (1) dealt with the problem of excitation in mechanically activated sense organs, designating the conditions which are responsible for the discharge of impulses over the nerves during excitation in the receptor. The available evidence seemed to him to indicate that excitation is to be correlated with definite changes in the surface layer of the receptor. The surface layer was observed to become thinner during stimulation, establishing a basis for the discharge of sensory impulses in a condition of altered permeability and of depolarization. The frequencies of discharge were found to vary with the conditions and amount of stimulation.

Fessard (24) set out to study the temporal relationships in brief cutaneous stimulations. He developed a technique (25) by which the finger was stimulated with the edge of the mirror of a Du Bois oscillograph. The deviations made by the mirror during contact were photographically registered, giving an accurate record of the pressure and its exact progress in time. By comparing this record with that of the course of the free mirror, he was able to determine the energy which was delivered to the tissues during contact. Stimulating the cutaneous receptors in this mechanical way, Fessard (25) found the liminal energy to be .01 *erg*, a value much lower than von Frey reported. He expressed the belief that the liminal energy for direct stimulation of unprotected receptors, such as those at the base of the hair, may be found to be as low as .001 *erg*. He also (26) determined that the latent time for mechanical stimulation of the

skin varied with intensity of stimulation. This relationship was not so clearly expressed as in Piéron's work, owing to the fact that the edge of the mirror of the oscillograph depressed the skin at a more rapid rate. He also ascertained that the reaction time for repeated (1000 per sec.) stimulation was shorter than for simple stimulation at any given intensity, excepting at high intensities where these reaction times were the same.

When the biceps was stimulated at its motor point, Renqvist and Mali (**56**) found the chronaxie for sensation of tension to be greater than that for contraction, and the rheobase value for sensation of tension to be less than that for contraction. But when the electrodes were applied to the body of the muscle, the chronaxie and rheobase values for sensation of tension and for contraction were the same, because in this case sensation of tension resulted only when contraction was induced. The chronaxie of superficial sensation, like a creeping on the skin, was determined to be greater than either of the other chronaxie values. Rothe (**60**) developed a technique by which he was able to measure the chronaxie of the *m. flexor Carpi ulnaris* in children prematurely born and in those born at normal time. He found the chronaxie to be higher in the prematurely born, but the degree of discrepancy became smaller with increasing age.

Bronk (**8**) stimulated the receptors in excised muscle by prolonged and interrupted loadings and stretchings, taking records of the afferent impulses discharged in each case. The muscle receptors seemed to adapt quickly and completely to interrupted short stretching stimulations; no change in the frequency of impulses was observable even after one thousand separate stimulations each of which was followed by only one second of rest. Prolonged stimulation, however, resulted in decreased frequencies of impulses, presumably because fewer and fewer receptors discharged as time progressed during the period of stimulation. The effect of fatigue, indicated by a diminution in the number of impulses discharged, was observed in the sustained stimulation of a single receptor. Keller and Loeser (**44**) recorded the action currents which were released when tension was applied to the gastrocnemius muscle of the frog. The results indicated that the number of impulses discharged was directly proportional to the amount of tension, and that at a given degree of tension the number of discharges recorded in repeated trials was approximately constant.

Griesbach (**33**) expounded the theory of a mutual relationship between irritation (*Erregung*) and fatigue in connection with meas-

urements of esthesiometric thresholds. The size of the threshold was alleged to differ with variations in the relative ascendancy of irritation or fatigue. The left hemisphere of the cerebrum was assumed to be chiefly concerned with mental work, and the right with bodily work. Consequently, irritation and fatigue resulting from work would be differently distributed in the two hemispheres. According as either factor prevailed over the other, the thresholds on the opposite side of the body were alleged to vary.

Temperature sense.—Weber believed that a change in temperature constituted the specific stimulus for the arousal of temperature sensation. Von Frey (29) has pointed out that Weber recorded an observation himself which apparently failed to meet the prescription of his own theory. He reported that a cooled key, applied to the forehead, aroused a cold sensation not only during the presentation but for some twenty minutes following its removal. Von Frey has explained that this is only an apparent exception to Weber's theory. Upon removal of the key, heat conduction proceeds from the surrounding area to that which had been cooled by the key, and provides a condition of temperature change adequate to excite the cold organs in the adjacent, previously unstimulated area. Cold is aroused instead of warm because of the less sparse distribution of cold as compared with warm organs.

In order to avoid contact and deformation of the skin in the stimulation of heat, Sullivan and Verda (66) stimulated the skin at two separate points with independent systems of cold and warm air. They were able to arouse heat when the two stimulators were applied at separations within the compass of 1 and 14 cm. The experience was localized at a point midway between the stimulators, and was described as being more extended than either of the separate components. Aside from references to such sensory qualities as tingle, sharpness, and prickling, the characterizations did not include descriptions of pressure. By removing one stimulator after heat had been aroused, it was discovered that cold was the more salient component, the one which gave heat its tingling and stinging character. Using a heat grill as the instrument of stimulation, Ferrall and Dallenbach (22) analyzed burning heat into cold, warm and pain. Then by using combinations of cold and warm, respectively between 9° and 20°C. and 38° and 44°C., and by exciting pain electrically, they effected a satisfactory synthesis of the experience. The investigators failed to arrive at a decision in regard to the ultimate or inherent nature of burning heat; whether it is a "complex" or mixed sensa-

tion including the several component elements, or a specific experience lying on the pressure-prick-pain continuum. Lowenstein and Dallenbach (**48**) determined the critical temperature for heat and burning heat by requiring their subjects to characterize the experiences which followed stimulations at every degree within the bounds of 40 and 51°C. The critical temperatures for heat varied from 40 to 46°C, with an average of 42.87 ± 1.07; those for burning or painful heat varied from 43 to 51°C., with an average of 47.09 ± 1.29. These results were interpreted as signifying that burning heat is an integration of heat and pain.

Drury and Dallenbach (**14**) undertook to find out how frequently during a sixty-minute period a cold organ may be stimulated without failing to respond maximally in consequence of fatigue. Cold spots were marked and stimulated at intervals of 5, 15, 30, 60, 180 and 300 sec. The sensations aroused were described in reference to a four-point scale—intense, moderate, mild and weak. The receptors responded to stimulation at all intervals in a large percentage of cases. No interval seemed to be distinctly more favorable, although the three longer ones amassed a larger number of responses than the three shorter intervals. The authors drew the cautiously discreet general conclusion that the same spot may be stimulated, without any danger of alteration in response as a consequence of fatigue, at least every fifteen minutes or five times per hour.

Bazett, McGlone and Brocklehurst (**5**) introduced light thermocouples into the skin near warm and cold spots and secured results in regard to latent time and rate of penetration. By correlating these results, they established that the cold receptors are located in the skin at a depth of .15 ± .1 mm., and the warm organs at a depth of .6 ± .2 mm. Accordingly, the warm receptors cannot lie in the sub-dermal tissues, but the Krause end-bulb may be the organ for cold. Bazett and McGlone (**4**) found that the latency for the sensation of heat was longer than that for either warmth or cold. The curves for latency of sensation were more complicated for warm than for cold stimulation. The authors asserted that this difference in respect to the nature of the latency curves for cold and warm sensation should be attributed to the fact that a warm stimulus usually arouses cold paradoxically, but that it is extremely rare for a cold stimulus to effect a paradoxical stimulation of warm receptors.

Laignel-Lavastine and Odinet (**45**) reported the case of a syphilitic who was unable to perceive degrees of thermal sensation on the left lower limb, all degrees of temperature being described as

tepid. In this same region, pressure sensitivity appeared to be normal, but that to prick was slightly diminished. After treatment, sensitivity to pain became normal and that to degrees of temperature began to show improvement. This apparent disjunction in cutaneous sensation was taken to denote that the impulses which aroused the several cutaneous qualities were transmitted over different nervous pathways.

Schlosberg and Carmichael (61) constructed a simple heat grill with two removable comb-like elements of copper or nails set in a wooden block. After warming one of the elements and cooling the other one, they were fitted together in position for the subject to place the hand or arm on the intermeshed elements. Barry and Bousfield (3) built a simple heat grill on the hot plate principle. It consisted of two wooden plates with two systems of screws, arranged in alternate or checkerboard series.

Dallenbach (12) developed a method for tattooing the skin so as to insure the possibility of stimulating the same spots at succeeding sittings. It consisted in the use of a capillary tube, the end of which was twisted on the spot until it had cut into the cutis.

Tickle.—Relying largely upon the writings of Ebbinghaus and Titchener, Hatano (35) set forth the specific qualities of the sensation of tickle, discussed its relationship to other cutaneous qualities and to instinct, and treated the topic of its localizability.

Pain.—Piéron (52) ascertained that the rate of propagation of impulses over a cutaneous nerve varied with the type of stimulation. The rates given in meters per second were: for burning 4.5, for pinching 12, for pricking 16, and for touching the skin 40. These results were related to the finding of Gasser and Erlanger, and others, that stimulation is attended by impulses traveling at different rates over the nerve.

Piéron (53) discovered that the reaction times for two different kinds of stimulation—burning and pricking—were not the same in certain parts of the body. In the head region, the reaction time for burning was found to be shorter than that for pricking; on the foot the reverse was true; and on the hand, both reaction times were the same. He related these results to the epicritic-protopathic theory of Head.

Previously, Naunyn, and Gad and Goldscheider, reported that a kind of summation effect appeared when the same point on the skin was repeatedly stimulated; thus, a weak stimulation eventually seemed to be stronger, or a non-painful one aroused pain. In these experi-

ments, the same spot was stimulated in successive trials. By stimulating two pain spots, lying within the space limen, at different intensities, and requiring the subject to make comparative judgments of intensity, Schriever (62) endeavored to avoid the possibility that repeated stimulations at the same spot might have led to injury in the previous investigations and thus to a change in conditions to account for the alleged summation effect. Under these conditions, Schriever failed to find any evidence of a summation effect, that is to say, there was no apparent change in intensity as a result of continued stimulations.

Cordotomy is a surgical method which is used to relieve patients who suffer from certain types of excessive pain. Stookey (64) was able to eliminate pain by this method without affecting thermal and tactual sensitivity in the region. He brought forward evidence to indicate that the impulses which occasioned pain were transmitted over fibers in the lateral spino-thalamic tract, while those which gave rise to temperature were dispatched over a tract more ventrally located, probably the ventral spino-thalamic tract.

Willemse (70) reported that Störring did not favor the view of von Frey in regard to the status of pain. Grouping pain with organic sensations, Störring took a position midway between Ziehen, who identified pain and unpleasantness, and von Frey, who listed pain as a specific sensation. Dumas (15) has just classified pain as a unique sensation, indicating points of distinction between it and unpleasantness. Burridge (9) has recently discussed pain—toothache in particular—in connection with his theory of excitation, according to which experience is said to arise from an interaction between calcium salts and colloids.

Sensitivity in the mouth.—Hirsch and Schriever (36) explored the tongue, the larynx, and the walls of the throat to determine the nature of sensitivity. Behind the circumvallate arch, the tongue was found to be insensitive to pressure. Pressure sensation was limited to the regions supplied by the trigeminal and glossopharyngeal nerves. Excepting on the tip of the tongue and in the neighborhood of veins where a condition of hypersensitivity prevailed, pressure sensation on the tongue was very similar to that on the skin. Pain was elicited in all parts of the tongue and throat, having a high threshold anterior to the circumvallate arch. Cold was most acute at two points, on the tip of the tongue and on the larynx, especially at the epiglottis. There was diminished sensitivity to cold at all other points. Warmth was well developed on the tip of the tongue and on the forward

edges; elsewhere there was hyposensitivity to warmth, and posterior to the circumvallate arch the tongue and throat were found to be insensitive to warmth. These results were related to cutaneous theory in such a way as to support the doctrine of specific energy of nerves.

Touch localization.—Although all of his subjects made improvement with practice in regard to accuracy of cutaneous localization, Renshaw (57) found that children between eight and eleven years made more rapid improvement than subjects of eighteen or more years of age. With vision excluded, the average error of localization for adult subjects was found to be larger than that for children, but when the subject was allowed to open the eyes after stimulation—during the act of localization—the magnitude of the average error was larger for children than for adult subjects. Renshaw concluded that ability to localize is essentially a matter of learning; and that children depend at first primarily upon touch and kinesthesis but with increasing age bring vision more and more into play in the localizing act. In order to test the hypothesis that adults rely relatively more than children upon visualization and less upon touch and kinesthesis in the act of localizing, Renshaw, Wherry and Newlin (58) compared the results of localizations of congenitally blind adults and children with those of visually capable adults and children. In the tactual-kinesthetic localizations, the average errors of blind adults were smaller than those of blind children, those of visually normal children were smaller than those of normal adults, and those of normal children were smaller than those of blind children. Using groups of children of different ages as subjects, Dunford (16) found gradual improvement in regard to accuracy of localization with increasing age, excepting in the cases of his two oldest age groups, eleven and fifteen, for which the average errors of localization were larger than for children at earlier ages. The results were thought to support, in general, the genetic theory; nevertheless, the fact that subjects at lower ages made highly and uniformly accurate localizations at the first sitting was designated as a point in defense of the modified nativist theory. In his medical practice, Söderbergh (63) had observed that his patients made confusions in regard to which toe had been touched. In experimental trials, he discovered that the correct digit was consistently indicated when the great or little toe was touched, but that confusion in regard to localization tended to be the rule in the case of the three inner toes.

Boring (7) raised the question as to why the magnitude for two-

point limen determinations should be several times larger than the average error of localization in the same region. Wundt and Head were cited as defending the view that two-point discrimination and localization represent different cutaneous functions. Boring took the position, however, that these two functions may have their basis in a single physiological function, and that the discrepancy in the results which have appeared from Weber down to the present are to be explained in terms of differences in training and in conditions of experimentation in the two specific situations.

Drugs and sensitivity.—Hoefer (**38**) gave subcutaneous injections of different concentrations of morphine, or its derivatives, regularly for a period of several weeks and made tests in regard to dermal sensitivity. Temperature sensitivity was not at all influenced by the injections. The curves for pressure sensitivity showed a sharp drop after injection, with subsequent sharp recovery. The effect was at all times "acute" in the case of pressure, that is to say, there was no indication of a tendency to adaptation to the effect after a period of continued use of the drug. Increase in concentration of the dose resulted in sharper changes in the pressure curve. The curves for pain sensitivity resembled those for pressure in the early stages, but after a period of regular daily injections the pain receptors manifested adaptation to the drug in that diminution in sensitivity did not follow the injections.

Willcutts (**69**) used a local anesthetic for abdominal operations, and reported the patient's account of sensations during application of anesthetic, making of incision, delivery of appendix to wound, and closure of wound. Most of the sensations were non-painful, but fleeting pain and nausea, in neither case severe, were occasioned by the manipulation of parts.

Size-weight illusion.—Ciampi (**10**) secured results which indicate that mental deficiency cannot be diagnosed accurately, as earlier writers alleged, in terms of the *signe de Demoor* or insusceptibility to the size-weight illusion. Previous investigators who reported the absence of this illusion in the subnormal are said to have failed in completely eliminating the influence of suggestion and in maintaining uniform conditions in their experiments. Rey (**59**) compared the results of normal and subnormal children at different age levels in regard to degree of prevalence of the size-weight illusion. It was found to be less pronounced, or absent, in the younger normal and in the subnormal groups, and in several cases the reverse of the illusion was demonstrated. He reached the conclusion that a certain

level of mental development was necessary to the occurrence of the illusion.

Usnadze (68) designated the size-weight illusion the "pressure" illusion. He also demonstrated a "volume" illusion in which case two objects of the same size but of varying weight appeared to differ in respect to size. Usnadze attempted to determine the bases of these illusory judgments. The size-weight illusion had been explained by Müller and Schumann in terms of secondary impressions which were thought to arise during the lifting of the weights and to have a decided effect upon the judgment. Claparède thought this illusion had its basis in different complexes of strain sensations which were aroused in the joints when objects varying in size but not in weight were lifted. Usnadze pointed out that neither of these theories proved satisfactory to account for the fact that the illusion continued to prevail when there was no lifting, that is to say, when the weights were applied to the skin. He explained the illusion on the ground that an attitude is built up in reference to that factor in respect to which the two objects differ. In the case of the "pressure" illusion, with objects varying in size but not in weight, the attitude is based on the character of size; in the "volume" illusion, with objects varying in weight but not in size, it is founded on the item of weight. Thus, the perception of smaller-larger difference influences the judgment of weight in the "pressure" illusion, and the perception of heavier-lighter difference affects the judgment of size in the "volume" illusion.

Perception of space.—Förster (27) called attention to the fact that in the act of mirror drawing the subject is required to disestablish, and to reorganize in a different manner, the elements which had previously been organized into his conception of space. In this learning situation, it was shown (a) that the motor acts were guided primarily by vision, not by touch; (b) that trial and error movements were made until it was visually perceived that one of them started in the right direction; and (c) that the performance was unsuccessful with the eyes closed. Experiments in which visual and tactual apprehension of form and size were compared led Bonaventura (6) to the conclusion that vision represented the better means to the realization of space. The non-visual or tactual perceptions were usually less accurate, and as a matter of fact vision was not entirely excluded by blindfolding the subject.

Katz (43) made a comparative study of children, adult and blind persons with regard to ability to identify or name a series of objects

which were presented tactually, or non-visually, and to designate the material substance out of which each was made. With regard to naming the objects, children rendered much quicker judgments than adults and tended not to depend upon secondary criteria. Adults were superior in designating the kind of material. The reaction times for naming were slightly quicker in the case of the blind than in that of children, but the former were most handicapped in the matter of indicating the kind of material. Merry (49) reported a study in which blind children were tested with regard to ability to apprehend embossed pictures of familiar objects. These children were greatly handicapped, the degree depending on the presence or absence of outstanding features, conceptions of perspective, and familiarity of objects.

Lamarque (46) ascertained that blind subjects depended upon cutaneous as well as auditory impressions in making judgments in regard to the proximity of an object, such as a wall. With hearing excluded, these subjects relied upon the impact of air waves on the forehead and temples. Lamarque found no evidence to support the view of the layman, that the blind have superior sensory acuity in hearing and touch.

Using both normal and pathological subjects, Renqvist (55) discovered that temporal judgments were relatively more independent and fundamental than spatial judgments in perceptions of movement. He concluded that spatial judgments have their neurological basis in the cortex, but that judgments of time probably are subcortical integrations.

Gault (31) gave dual (visual and tactual) stimulation in the presentation of speech sounds to deaf subjects through the instrumental means of his "teletactor." The subject was found to learn more rapidly by dual than by unimodal (visual) presentation.

Craig (11) determined that an unfilled extent, apprehended cutaneously, was judged to be 18 per cent longer than a filled extent of the same magnitude, and 13 per cent longer than a partially filled extent. By comparing the unfilled extent with a variable of the same kind and size, a time error amounting to 2 per cent was discovered. It was inferred, therefore, that the two figures just given are exaggerated by that amount.

Perception of movement.—Mukherjee (50) set out to test the law of Vierordt which stated that the magnitude of the space limen at any point on the limb would be found to vary inversely with the distance from the axis of rotation. He made determinations at

different points on the volar surface of the right arm, and found, in accord with the law, that the limen for the fingertip was smallest and that for the tip of the middle finger was smallest of all. The law was confirmed in general, except that since there was improved sensitivity in the neighborhood of joints, and especially around the shoulder, as compared with interjoint areas, the results did not seem to validate the law without reservation.

Renqvist (55) was concerned with the perception of bodily movement, and indicated the comparative inadequacy of pathological subjects, such as those blind from birth or with certain brain traumas. Leriche (47) found that the articular ligaments were supplied with nerves adequately to provide for sensitivity in the peri-articular regions. Under normal conditions, stimulation failed to arouse sensation, but in cases of altered constitution of the blood, especially in cases of excessive calcium, extreme pain was reported to occur.

Lifted weights.—Turner (67) found that previous stimulation had a modifying influence on the psychophysical judgment. In his first experiment, two distinctly heavier or distinctly lighter weights were compared just before each comparison in his regular series of weights. In this case the retentive trace of the preceding comparison was effective in shifting the judgments in the following or regular series in the direction of the preceding weight. More heavier judgments appeared in the comparisons in the regular series when the preceding pair of weights were distinctly heavier, and more lighter judgments were made after preceding comparisons of two distinctly lighter weights. In his second experiment, Turner presented three weights, the last two of which belonged to his regular series. The subject was required to compare the second with the first weight before he compared the third with the second. Here the results showed a tendency in the second of two successive judgments to a reversal of the first judgment, more lighter judgments following previous heavier ones and *vice versa*. Turner did not think that his results supported the configuration doctrine.

Guilford and Park (34) interpolated a 100 or a 400 grm. weight between each presentation of a 200 grm. standard and one of its variables in a lifted weight experiment. He found that the resulting difference limen was enlarged and that there was a shift in the psychological values of the variable weights relative to the standard. The results were interpreted as favoring the theory of configuration, in that the comparative judgment was made in terms of an alteration

in potential occasioned by lifting the interpolated weight, which changed the dynamic neurological processes underlying the judgment.

Gahagan (30) compared the precision of judgments in experiments with lifted weights (a) when the standard was followed by its variable, (b) when the standard was followed by two variables with both of which it was compared, and (c) when the standard was followed by seven variables with each of which it was compared. Although the subject is said to have retained no clear impression of the standard in terms of which to make the seven comparisons in the third series, the limen and precision values are of the same order as those in the other series. Therefore, although made in terms of an absolute judgment, they show the same degree of precision as regular comparative judgments. Fernberger (20) found that normal curves of the psychometric function resulted in a lifted weight experiment in which no standard was used, but in which the subject was required to evaluate each weight in terms of an absolute judgment. However, precision of judgment was lower and the interval of uncertainty much greater in this experiment than in the regular series in which a standard was used.

Using four different types of instruction for prescribing and defining the categories of judgment, Fernberger (19) secured results which revealed that the effect of practice tended to diminish "equal" and "guess" judgments. In this study as well as in another (21), he emphasized the importance of a stable attitude in psychophysical work.

Hoagland (37) called attention to the fact that the logarithmic relation known as the Weber-Fechner law has not been demonstrated except in the mid-regions of intensity, and even there it has been demonstrated with no high degree of precision. Referring to experiments in vision, touch and kinesthesis, he attempted to show that this alleged logarithmic relationship is probably a function of the *all or none* law. Thus, with progressive increments in intensity of stimulation, more and more receptor cells are excited.

Ponzo (54) called attention to the fact that there is a psychological difference between the same amount of gradual increase and of gradual decrease in the perception of weight at any point on an intensive continuum, and that this fact should be taken into account in all psychophysical work having to do with the perception of weight.

The sense of vibration.—Petzoldt (51) performed experiments having to do with localization, threshold values, masking and apparent movement of sensations of vibration. If both hands were placed on

a rod which was connected with a vibrator, the direction of the source of stimulation could be determined in terms of differential stimulation in the two hands. With the arms crossed, confusions in regard to localization were frequent. When one hand only was placed on the rod, more intense stimulation was required for consistent judgments in regard to the direction of the source of stimulation. Localizations by the feet were about as accurate as those by the hands. The threshold values of the hand and foot were found to be approximately the same. With regard to masking, Petzoldt found that vibration was perceived only in that one of the hands which was more intensively stimulated. In view of the fact that the weaker stimulation could be felt when the hand which was being stimulated more intensively was withdrawn, he concluded that masking took place in the cortex. Apparent movement of vibratory sensations was demonstrated in two ways: (a) by withdrawing the hand which was stimulated at higher intensity, and (b) by altering the intensity ratio so as to make the more intense stimulation shift to the hand which had just been undergoing weaker vibratory stimulation.

Von Frey (**28**) expressed the opinion that Katz and Noldt (*Zsch. f. Biol.*, 1927, 86, 525–526) did not succeed, as they alleged, in demonstrating the independence of vibratory sensations as against pressure sensations by stimulating the former at such low energy that pressure was not excited. Von Frey has pointed out that they worked in a very sensitive part of the skin—the tip of the finger—and he has calculated that the energy of their stimulus was supraliminal for pressure. He also took issue with them in regard to their assertion that movement is a specific character of sensations of vibration, and pointed out that vibration can be occasioned by the stimulation of a single receptor.

One of a series of lectures by Katz (**42**), entitled "The Vibratory Sense" (pp. 90–104), is related to this topic. The treatment is general, setting forth chiefly the points of distinction between the sense of vibration and that of pressure.

Kampik (**41**) compared deaf and hearing subjects in regard to ability to perceive vibrations. Through vibratory sensations, deaf subjects were able to distinguish between tones and noises at once, but hearing subjects were not able to do so until after a period of training. Within a limited region, pitches as close together as the semitone could be discriminated. The upper threshold was determined at about 1,300 and the lower at 16 vibrations per sec. Mate-

rials were distinguished and verbal characterizations appropriate to each kind of material were given. Contrary to the assertion of Katz, Kampik found that a fatigue effect, manifested in diminished sensitivity to vibration, followed sustained vibratory stimulation.

Anderson (2) reported that sensitivity to vibration and to passive movement decreased with age, and that specific changes in each of these modes of sensibility followed the onset of particular diseases. He expressed the belief that these experiences are relayed over different nervous pathways in the spinal cord, and perhaps in the brain also. Epstein (18), using a tuning fork to excite vibratory sensations, showed that vibratory stimulation is referred to the exact homologous spot on the opposite side of the body. In view of the fact that, in cases of lesions, the length of time taken for these sensations to arise may vary, or sensation be diminished or altogether lacking, vibratory sensation was emphasized as having diagnostic significance.

Von Goetzen (32) determined that relatively few physicians observed that tactual impressions as well as auditory were used in percussion examinations. He found that the limits of the heart and lungs could be determined by percussion as well without hearing as with it. In order to eliminate the influence of knowledge of anatomy he invented and used a "perkussionsphantom," a contrivance in which the position of the object to be localized by percussion could be shifted. Again, tactual impressions were found to be as effective as were auditory. It is von Goetzen's opinion that the diagnostician uses vibratory sensations in percussion examinations but confuses them with auditory experiences.

Pressure and affection and emotions.—In order to test Nafe's contention that affection can be resolved to bright and dull sensations of pressure, Hunt (40) presented a series of colors to trained and naïve subjects, requiring them to report the nature of any pressure sensations which attended the observation of each color. One week later, the same colors were presented with the instruction to report in regard to the pleasantness or unpleasantness of each color. Computation of correlation coefficients resulted in the revelation of a significant relationship between affection and bright and dull pressures. This may be interpreted as indicating either that affection is bright and dull pressure, as Nafe asserts, or that affection is accompanied by bright and dull pressures, which is the view to which Hunt subscribed. In another study, Hunt (39) presented pleasant and

unpleasant emotional situations, demanding that his subjects report if experiences of bright or dull pressure attended the observations. Thirty-six of the fifty-nine introspective reports included references to bright or dull pressure, bright pressure accompanying pleasant and dull pressure unpleasant emotional stimulation. Comparing these results with those of his earlier study, Hunt reached the conclusion that the pleasantness in an emotion was no more intense than that in simple affection, but that the unpleasantness in the emotion was much stronger than that in the affection.

Protopathic and epicritic sensibility.—Stopford (65) defended Head's theory as against the contentions of Trotter and Davies, Boring and Shafer. He undertook to establish that the qualities of protopathic sensibility are integrated at the level of the thalamus, while those of epicritic sensibility have their neurological basis in the cortex. D'Antona (13) related protopathic sensibility primarily to sympathetic, and epicritic to cerebrospinal pathways. Normally both systems operate together, but in certain pathological conditions the epicritic factor is disengaged, allowing the protopathic to manifest its distinctive characteristics. Piéron (53) advanced the view that impulses arising from stimulation by burning are transmitted over delicate, more or less unmyelinated nerve fibers, those for stimulation by pricking over larger, medullated fibers. Owing to the fact that each has a different reaction time, burning is classed with protopathic and pricking with epicritic sensibility.

Autonomic nervous system.—Believing that the autonomic nervous system had an important functional relationship with cutaneous sensibility, Dusser de Barenne (17) performed experiments on animals to determine the influence of sympathectomy upon dermal sensitivity. Removal of the sympathetic chain on one side resulted in homolateral disturbances but did not affect sensitivity on the opposite side. The same conclusion was supported by clinical evidence.

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THE PERCEPTIONS AND MECHANISMS OF VESTIBULAR EQUILIBRATION

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The last survey of experimental studies on the psychological functions related to the semicircular canals was limited, in large measure, to problems that were distinctively sensory and perceptual (41). It has seemed advisable to broaden the scope of the present survey so as to include a fair sampling of the physiological and anatomical studies that may have a bearing upon or contribute to the psychological functions. We shall also consider some of the findings of the clinical laboratories in so far as they seem to relate to psychological and behavior problems of balance. We shall report, in turn, upon (i) general surveys, (ii) apparatus and methods of stimulating vestibular reactions, (iii) perceptual functions related to the vestibule, (iv) modes of response, (v) anatomy and physiology, and (vi) clinical and pathological material.

(i) *General Surveys.*—The period under review has brought forth several general surveys of labyrinthine functions somewhat better in quality and less prejudiced than were one or two of those which appeared shortly after the war. Camis (16), for example, has written a most comprehensive survey of the entire field. He has made use of a bibliography of more than 800 titles and 65 figures serve admirably to clarify the discussion. The book begins with an account of vestibular work up to and including Flourens. A chapter on the anatomy and physiology of the labyrinth, together with a general survey of the development of the labyrinth through the animal series, appears to be well done. Camis is to be thanked for a faithful review of surgical methods of studying the labyrinth. He is fully aware of the tremendous difficulties which have attended this method of approach and his whole discussion can hardly help but lead to a refinement in technique. The method of surgical insult will continue to be of value only in so far as its attack on the labyrinth can be confined and localized. Camis' review includes an appraisal of the effects of partial and complete destruction of the labyrinth, an account of the effects of localized stimulation of various portions of the inner

ear, some discussion of the relation between the labyrinth and sense perception, and of the general nervous connections between the labyrinth and other parts of the organism, especially the eye and the autonomic system. The survey is concluded with the argument that the vestibular apparatus is probably a collection of receptors which have a number of different reflex functions. Not all of these functions have to do with actual movement. On the contrary, they are concerned in the maintenance of normal posture and in the origin of such experiences as vertigo, nausea, and the like.

A short but highly adequate survey of the rotational method and of the so-called practice effect has been made by Holsopple (**53**). The bibliography is useful. In a study of the relation between the ear and the origin of language and writing, Tullio (**124**) argues for the dependence of certain types of perception upon utricular structures. It is assumed, for example, that the perception of pure tones and clangs is mediated by the cochlea, but that noises are perceived with the aid of other structures. It is intimated that the perception of tonal direction may be mediated by the semicircular canals. Baldenweck's (**2**) survey of the vestibular functions is written largely for medical students. On the whole, the study is competently done and useful for beginners. It gives a rather useful survey of the anatomy and physiology of the semicircular canals, a fairly penetrating description of various kinds of nystagmus, a somewhat studied classification of modes of stimulating the vestibular functions, and a brief excursion into the clinical field.

Of less general significance are Thornval's experimental studies, a series of five lectures by McNally, and a review of the clinical material by Demetriades (**24**). Thornval (**119**) reviews a good many different facts primarily for the sake of furnishing a proper perspective in which to place his own experimental work. This consists largely of a fresh determination of familiar principles. McNally (**78, 79, 80**) is lecturing primarily upon the anatomy and physiology of the inner ear. His papers, especially the second and third, afford a fairly good introduction to vestibular problems.

Of the many anonymous or secretarial reports of otological congresses in France, Germany, and Italy, we shall mention only one (**1**). Twenty of the twenty-nine papers read before a French society deal with nystagmus and its clinical application. The papers discuss, for the most part, methods of producing nystagmus, the distinction between centrally and peripherally aroused eye movements, the importance of a careful study of nystagmus as an aid to the diagnosis

of disturbances in the labyrinth and in the central nervous system (after the fashion of Bárány) because of the light they may throw on the localization of cerebral abscesses and tumors.

(ii) *Apparatus and Methods.*—The period of research under review has seen a continued improvement in apparatus and much refinement in method. The interest in vestibular problems created by the war made it absolutely imperative that various forms of stimulating the vestibular receptors be refined to such an extent that a nearer approach to a one-to-one correspondence between stimulus and effect might be achieved. Definite progress in this direction is being made. On the side of apparatus, Dallenbach (**23**) describes a rotation table made out of parts of used automobiles. The apparatus is inexpensive but highly stable and suitable, therefore, for a variety of experiments. Zubizarreta (**132**) has constructed a bronze model of the semicircular canals as an aid to clinical observations. Cords (**18**) and Ohm (**95**) have fallen into an argument concerning methods of studying eye movement. At the end of a review and criticism of mechanical devices for measuring eye movement, Cords asserts that high precision in the study of eye movements is to be obtained only by optical methods. Ohm replies, partly, by way of a history of methods of measuring eye movements and, partly, by a defense of his own methods which are largely mechanical. In a general article on nystagmus Lebensohn (**70**) reviews briefly current research, mostly clinical, on eye movement and makes a small contribution to nomenclature. The method of anchoring a mirror over the eye has been adopted by Meyers (**82**) in order to obtain differential records of eye movements produced by winks, tremors of the eyelids, pulsation, head movements, and fatigue. Meyers reports that each of these eye movements can be distinguished from nystagmic movements. He reports further that objective records can be got indicative of pathologically induced nystagmus which differ significantly from normal nystagmus movements. No one, however, has as yet excelled Dodge and his students in these techniques (**25**). Fox and Dodge (**38**) describe an apparatus for measuring the contraction and relaxation of individual eye muscles. It was found that fixation of the fundus orbiti was absolutely essential if proper control of the eye muscles was to be achieved. Under these conditions reciprocal innervation of the inferior and superior recti appeared when the subjects were rotated around their longitudinal axis. Under rotation around the bi-temporal axis, analogous facts were gained save that more irregularities appeared. Somewhat similar studies had already been done by

de Nó (88, 89) with negative results; but Fox and Dodge are inclined to suspect that these negative results were due to defective technique. The application of action current measurements has been attempted with considerable success by Meyers (82). The electrodes of the electrocardiograph were attached to the temples and graphic records of the action currents of the eye muscles in voluntary and nystagmic eye movements were obtained. Each type of nystagmus was found to give a characteristic record in which the slow and quick components were easily distinguished. Meyers concludes from his study that the quick component is due to active contractions of the antagonistics of the muscles producing the slow component. Steinhausen (113) appears to have found a new method for observing directly the physical events in the ampullae. It would seem that this method ought to be further examined partly because of the assertion that currents in the endolymph are said to cause actual movement of the cupula. This has been one of the long-standing problems of vestibular excitation.

All of the classical methods of stimulating the vestibular apparatus still continue in use but each has been surrounded by more adequate control. Most experimenters are more keenly aware than they were of the difficulties involved in localizing the effects, say, of surgical, galvanic, or caloric techniques and this very awareness has contributed in no small measure to a better type of experimentation. These observations are true, in particular, of the surgical method. Nylén (91), for example, reports that extirpation of various parts of the labyrinth is always accompanied by hemorrhage in nearby regions. He would argue, therefore, that nystagmus may be due to these pathological changes as well as to direct stimulation, especially when a change in the position of the head alters the pressure in the labyrinth. As we shall see, pressure phenomena have enjoyed a revival of interest. Benjamins and Huizinga (9, 10) continue their series of studies on the pigeon. Removal of the pars superior seemed to have the same effect as removing the entire labyrinth save that rotary eye movements were not disturbed. Removal of the pars inferior, however, was accompanied by disturbances of rotary movements of the eyes. These investigators concluded, therefore, that the pars inferior must be somewhat restricted in its functions. Groebbels (42, 43, 44, 45, 46), likewise, continues his long series of studies on pigeons. He has become, without doubt, one of the most competent users of this technique. A modification of the surgical method has been used by Rizzolo (103). The study was made on ten dogfish (Galeus Canus).

Bilateral sectioning of the olfactory tracts and the optic nerves was effected in conjunction with bilateral destruction of the labyrinths. The latter alone seemed to cause disturbances of equilibrium.

Galvanic methods of stimulating the canals have been used freely by Huizinga and Dohlman. In a series of experiments on the head and eye movements induced by galvanic stimulation of the ear, of pigeons, Huizinga (**56, 57, 58**) confirms results already obtained by Jensen. Although the reaction to galvanic stimulation was nearly normal after extirpation of the labyrinth, it gradually diminished until only a weak reaction resulted from the intense stimulation. This fact, together with the fact that the reaction vanished almost entirely after a period of time, was explained by the discovery that the eighth nerve and Scarpa's ganglion were found to have degenerated. Further studies on the extirpation of this ganglion and successive extirpations after long intervals of the one labyrinth and then the other led Huizinga to conclude that "the galvanic reaction is normally aroused by stimulating the vestibular nerve and especially its peripheral parts." The first half of Dohlman's study (**26**) is devoted to an historical review of the galvanic method. The review appears to be competent and furnishes a good introduction to this method. The review is summarized in such a way as to say that, under normal conditions, the passing of a galvanic current through the labyrinth results in nystagmus in the direction of the current and a tendency to fall to the opposite side. A period of stimulation is accompanied by a feeling of dizziness. In contrast to early investigators (Hitzig, Strehl, and Erb), who maintained that these results were due to a direct stimulation of the brain, and in contrast to Breuer, Jensen, and Bard, who concluded that they were due to stimulation of receptors in the labyrinth, Dohlman argues that the reaction is due to direct stimulation of the vestibular nerve. This argument is based on the proposition that reactions to a galvanic stimulation may occur after the destruction of the labyrinth. In support of his argument, Dohlman (**26**) turns to his own experiments. He concludes (1) that the galvanic reaction has no significance for judgments about the function of the peripheral labyrinth or of the sensory epithelium, (2) that the galvanic reaction is mediated in the vestibular ganglia, an interpretation which is taken to mean that ganglionic cells capable of such functions reside in this structure, (3) that the labyrinth must exert a genuine tonic effect since the falling reaction can be produced after the removal of the labyrinths by destroying the vestibular ganglia on one side, and (4) that modification of tonus in eye reflexes after

injury to the vestibule implies a modification of the galvanic reaction by means of persistent vestibular reflexes. A similar result was obtained from rabbits by Dohlman and Engvall (27). Blohmke (14) followed faradic excitation of the brain stem with histological examinations which showed that the point of application of the stimulus was not truly superficial but penetrated much more deeply to the brain stem. That coördinating tissue rather than a motor nucleus was affected seemed probable in the light of the fact that there was a distinct latent nystagmus.

Caloric methods of stimulation have not seen as much improvement as have the other methods. There has been, however, an attempt to apply the method to new variations in the type of phenomena studied. In an earlier work Leise (72) had shown that a minimal effect of cold stimulation applied to the lower ear was produced when the head was inclined about 30 degrees toward the horizontal. In a newer study (73) the same investigator shows that rinsing the ear with cold water has no effect upon the nystagmus elicited from the other ear by warm water. He concludes, therefore, that the cause of the inhibition of nystagmus to be observed under strong stimulation in the caloric test is to be sought not in the effect of the cold upon the auditory nerve but in a sensory labyrinth effect in the form of vestibular over-stimulation. Schmaltz (107) maintains that the streaming movements in the endolymph after thermal stimulation have a negative acceleration until a zero point is reached, after which there is a compensatory streaming in the opposite direction. He finds a significant correlation between the rate of movement of the endolymph current and the observable responses described by Fischer and Veits (33). Errecart, also (29), finds a relation between the direction of the endolymph currents under caloric stimulation and the resulting nystagmus. In a review of a previous work an attempt was made to correlate the findings of such clinicians as Hofer and Meyer, Bárány, Brünings, and Kobrok. The paper is for the most part an attempt to validate the clinical value of the caloric and rotatory tests. A similar summary and appraisal of research on caloric stimulation is given by Veits (125). Confirmation of the observation that the position of the head is highly important for the nature of the equilibratory responses under caloric stimulation is furnished by Fischer and Veits (33). The character of the responses are determined by the plane of inclination of the head preceding irrigation. For cold irrigation the responses are opposite in direction to the antecedent head movement and for warm

irrigation the head movement is in the same direction. In the median plane, the duration of the responses is found to be proportional to the sine of the angle of inclination with a maximum at 90°. In the sagittal plane, maxima are found at 45° but some variable factors obscure these latter facts. It is noted, for example, that the duration and direction of the equilibratory responses are related to the interval between inclination and caloric stimulation. Some of these interpretations appear to stand in contrast with interpretations made by Bárány (**3**). This is effected through a description of the conflicts that may obtain in the vestibular apparatus as a result of such factors as the inclination of the head during warm or cold water flushing in one or both ears. Any combination of these factors will have a determinable effect, but some of the effects may be prepotent over others. It is essential, therefore, in any caloric study, to describe not only the observable responses but to take account of the dominance which one set of circumstances may have over another set.

Rotational methods of exciting the vestibular mechanisms have long since passed into medical practice along with the caloric and galvanic methods but in spite of the critical work of Dodge and others not much improvement has been effected in them. Errecart (**28**) has reviewed the whole matter from the clinical point of view. Such clinical aids as the topolabyrinthograph, a device for determining the position of the horizontal canals, the Bartels glass for controlling convergence and fixation of vision, and the like, are critically examined. Support is given to the traditional belief that a reaction of less than fifteen seconds or of more than forty seconds is indicative of pathological conditions. From the clinical side the rotation method receives favorable criticism also from Ohm (**94, 97**). Tiumjanzeff (**120**) has used a slight modification of the method with pigeons. He finds that rotation with the bill toward the periphery induces greater nystagmus than when it points toward the center. Terazawa (**116**) used the method of rotation in studying the deaf-mutes at the Tokyo Deaf-Mute School. Using a method of rotation perfected by Bartels, de Nó (**89**) studied the oculo-motor reflexes of dogs. The experiments were made with the animal's head in the normal position. Three types of reflexes were found, viz., (1) nystagmus, (2) a tonic reflex resulting from centrifugal force, and (3) a quick contraction occurring at the beginning and end of a rotation. It was possible to isolate each of these responses since (a) when the head was in the normal position and the rotation was about a vertical axis, nystagmus did not occur in the vertical and oblique muscles. The resultant

reflexes in these muscles are, therefore, a combination of the second and third types. (b) If the animal is turned slowly with constant velocity the first and third reflexes finally die away, leaving only a second. (c) The second reflex, a response to centrifugal force, is eliminated by locating the axis of rotation between the ears. (d) The first and third reflexes occur at the cessation of rotation as well as at the beginning. The nystagmus, however, differs from the third reflex in that the former is reversed in direction at the end of a rotation, whereas the latter is not. Typical curves resulting from combinations of the three reflexes in the same and opposing directions and in varying strengths are shown and analyzed.

Recent experimentation has seen renewed emphasis upon the effects of pressure on the ear. Errecart (**30**) has discussed the problem in a rather general way from the clinical point of view. It is observed that the nystagmus produced by the pneumatic method may be both extensive and positive when caloric and rotary tests give no results. Dohlman and Engvall (**27**) draw contrasts between the pressure method and the galvanic method. The marked difference in the effect of the two methods is illustrated by the observation that the maximal rate of movement of a rabbit's eye under pressure stimulation was 70 per second, whereas galvanic stimulation gave a frequency of response as high as 150 per second. De Juan appears to have used this mechanical method most frequently. One of his studies (**59**) is given over to a description of the complicated ocular movements evoked both by compression and aspiration. In two other papers (**60, 61**) de Juan has gone at the problem more searchingly. A syringe was inserted through the bony wall of the utricle in such a way that the perilymph could be drawn out or put under pressure. In other words, currents were produced in the endolymph to and from the ampulla. Dohlman's method of placing a rubber cap on the cornea was used to record the eye movements. In general, compression was found to produce more violent response than aspiration, especially when the animal reclined with the operated side up. The nystagmus was toward the operated side after compression and toward the intact side after suction. The eye movements were found to have horizontal, vertical, and rotatory components. Of these, the vertical movements were most distinct, especially when the changes in pressure were rapid. Under certain circumstances aspiration following compression did not produce nystagmus if the compression had been very great. Meurman (**81**) has related these facts to increase in intracranial pressure. A spontaneous nystagmus on the

side opposite to an artificial labyrinthine fistula was prevented by increased intracranial pressure. Under certain circumstances strong suction also produced nystagmus unless it had been preceded by compression. A suction applied to the inner ear was observed to diminish nystagmus due to compression. Portmann (**100**) applied pressure to the large blood vessels in the neck rather than to the ear itself. Four dogs were used as subjects. After a preliminary survey of the subjects which gave data regarding pulse rate, pupillary condition, mucous coloration, ocular-cardiac reflexes, and vestibular excitability, the animals were rotated twenty times in twenty seconds, first to the right and then to the left. The observations of the induced nystagmus were taken before and after compression and ligature of the blood vessels in the necks of the animals. No reliable difference was found between nystagmus values before and after the ligature, either of the carotid or the vertebral arteries.

The various modes of modifying stimulation of the inner ear through the use of drugs is most difficult to control. Only two experimenters seem to have chosen this method. Berggren (11) has studied the effect of bulbocapnin on both rabbits and men. Small doses (0.05–0.01 grain) have no effect on optical nystagmus. In certain types of spontaneous nystagmus, however, a decrease or even complete cessation of both nystagmus and vertigo was effected by doses of 0.1 gram injected subcutaneously. The greatest effect appeared about fifteen minutes after administration and remained effective approximately twenty-four hours. Ross and Fish (**106**) have also studied the effect of drugs. The average duration of nystagmus in ten normal dogs was from 18.2 to 22.4 secs. With 1 c.c. of 1 per cent epinephrine sol. per kgm., the average was 17.1 to 19.8 secs.; with .5 to 1 c.c. of 5 per cent $NaNO_2$ per kgm., 14.4 to 16.6 secs.; with 10 mgm. of cocaine hydrochloride per kgm., 16.0 to 18.3 secs.; with nicotine, .5 mgm. per kgm., 13.9 to 16.8 secs.; with 1 mgm. atropin sulphate per kgm., 17.7 to 18.8. In general, the drugs that decreased nystagmus after rotation had severe depressive results. Bearing some resemblance to these studies is the note of de Kleyn and Versteegh (**66**) on the effects of alcohol. Variable relations were found between degrees of rotation, labyrinth extirpation, removal of one or both maculae and alcoholic nystagmus. There is also a note by Leroux and Causse (**74**) on the vestibular effects of alcoholic intoxication. The effect is said to be the same as that exerted by atropin.

It is a little unfortunate perhaps that further work has not been

done on the stimulus value of practical or industrial situations. Schubert's study (108) on the effects of spinning movements in airplanes appears to be the only contribution from the aviation service. Because of its clinical importance, miners' nystagmus has gained more attention. Haycraft (48, 49) describes the chief subjective symptoms of coal miners' nystagmus as consisting of poor vision, headache, photophobia, giddiness, insomnia, and apparent movement of stationary objects. There are also marked constrictions in the color sensitivity of the retina. A variety of physical symptoms are also described, the first of which is nystagmus. Haycraft believes that ocular movement is the result of defective illumination supplemented by general exhaustion of the nervous system; that is, a neurosis is said to contribute as much to the syndrome as does defective illumination. Similar data are given by Roche (104). The problem of miners' nystagmus has been much studied by Ohm. In an early study Ohm (92) sought to evaluate the amplitude and frequency of such movement. In contrast to values of only 8 or 8.5 grams for the power of the rectus muscles in maintaining voluntary fixation against resistance applied by means of Fischer's corneal cup, Ohm found that eye movements were substantially unaffected when opposed by a 30-gram weight and still persisted under a load of 50 grams and more. In a much more elaborate study Ohm (99) seeks both to distinguish and to correlate nystagmus of vestibular origin and nystagmus induced under industrial conditions. His argument, for the most part, centers on the proposition that nystagmus induced by rotation is essentially vestibular, whereas miners' nystagmus is initiated in some central nucleus. Lebensohn (69) has sought to draw a similar contrast between vestibular nystagmus and some of the phenomena characteristic of car-sickness. A rotating striped drum was used to induce optical nystagmus, while a stomach balloon was used to record gastric effects. Rotation and douching the ear both increased gastric tone, but since the same effect was gained by irrigating the skin in the neighborhood of the ear, Lebensohn concluded that the gastric response was the function of stimulation of the cutaneous nerves rather than of the labyrinth. In other words, the symptoms described as car-sickness do not seem to depend upon optic nystagmus.

(iii) *Perceptual Functions.*—The perceptual functions aroused by and mediated through vestibular stimulation still remain under dispute. In a discussion of the question as to whether the sense of rotation is mediated by the semicircular canals, Fischer and Sommer (32) stimulated by the caloric method subjects who were con-

genitally blind, subjects who had become blind in later life, and normal subjects who kept their eyes closed in a dark room. Since three-fourths of the subjects experienced a sense of rotation apart from visual stimulation, even though the intensity of the stimulation was increased to heroic proportions, the authors conclude that the experience of rotation may be elicited by caloric stimulation independent of visual experiences.

Intense argument still continues concerning the relation between auditory localization and the semicircular canals. Bard, for example (**4**), argues that the perception of sound depends upon reflex adjustment of the canals to the components of the sound complex. Holsopple (**53**), in a general study of the vestibular perceptions, argues that there is a form of spatial perception which cannot be explained in terms of sensory data without reference to the non-auditory parts of the ear. By implication, at least, the opposite point of view is taken by Young (**131**), who explains localization in terms of "muscle tonus" and general functions of the organism as a whole. Higginson (**52**), in a study of the performance of the white rat in a rotated maze, found "no experimental evidence for the claim that the white rat possesses a sense of direction located in the semicircular canals, or elsewhere, by virtue of which it is disturbed when the maze, previously learned at one position, is rotated to new cardinal positions." A similar conclusion might be inferred from the studies of Leuba and Fain (**75**). Leise (**73**), in an argument with Noltenius (**90**), also disputes the view that localization is mediated by the canals. He draws, first, a distinction between sensation and space feeling. Space feeling is described as the idea of an infinite space which can never be the object of perception. Since there is no sense by which we can perceive space, this function must rest upon a congeries of senses. Since the activity of the vestibular apparatus takes place without consciousness, the observed experiences of disorientation must be due to the "ramifying systems" which are connected with the canals. In other words, the vestibular apparatus is a receptor but not a sense organ. This same problem has been discussed from the clinical point of view by Fischer and Kornmüller (**36**).

One of the most puzzling circumstances in all work upon the vestibular functions lies in the fact that nystagmus and other types of equilibratory movement may appear without stimulation initiated within the vestibule itself. The facts just reviewed point in this direction. Keleman (**62**) has described a variety of other circumstances under which spontaneous nystagmus may appear. An

illuminating table of spontaneous nystagmus compared with experimentally induced nystagmus is presented for the guidance of those who easily associate every disturbance of equilibration with the experimental technique itself. De Nó (87) has also studied this problem. Patterns of nystagmus following unilateral extirpation of the labyrinth were found to show no consistency from animal to animal or from time to time in the same animal. In other words, de Nó is arguing that the total condition of the nervous system as well as the insult to a particular receptor may have a bearing on the character of the responses. Any abnormal position of the head, even months after an operation, is likely to induce spontaneous nystagmus.

The effect of the position of the head on spontaneous nystagmus has been studied by Sommer and Yaskin (109). Changes in the position of the head would cause changes of pressure in the whole vestibular apparatus, especially in the horizontal canals. The relation between this work and recent studies on the effect of compression and aspiration has been discussed above. Spiegel (111) and Demetriades (24) find that the state of the vegetative nervous system has a pronounced bearing upon vestibular functions. This becomes true by way of the contractions of the arteries, the permeability of the vascular walls, and oscillations of blood pressure in the ear. Similar effects may be induced, according to Lunedi (76), by changes in the skin of the mastoid area, on the posterior surface of the neck and the mucous membrane of the nose. Lunedi argues that nerve impulses arising from sense organs in these areas act upon brain centers which are subject also to innervations from the labyrinth.

The most perplexing phase of this problem is to be found in direct stimulation of the visual receptors. Huddleston (54) remarks this fact by way of the observation that marked differences in nystagmus were found between pigeons which were rotated in the dark as compared with rotation in the light. Recent studies have brought about a marked increase in interest on autokinetic phenomena and their relation to nystagmus. Ohm (93) asked seven subjects, who were suffering from ocular disorders, to fixate a luminous point and to maintain fixation after all lights had been extinguished. All but one displayed eye movements having a characteristic nystagmic jerk. The direction of movement was fairly constant for each observer and the frequency varied from 30 to 72 per minute. In other words, the movements seemed to differ from normal dark-nystagmus in that they began immediately after the room was darkened and were jerky rather than pendular. Ohm attributed the movements to vestibular

factors which might be overcome by attempts at fixation. This study has been supplemented by an account of similar phenomena in subjects suffering from diseases of the optic nerve (96). As we have seen, this conception lies at the basis of his study of miners' nystagmus. Cords and Nolzen (21) describe in detail the methods for inducing optokinetic nystagmus. They discover that this type of nystagmus is a function of the velocity of the stimulus and of the degree of concentration of attention. The nature of the phenomena in cases of hemianopsia, astereognosia, and motor aphasia is also described. In a further study (19), Cords attacks Lieri's theory to the effect that after-images of movement can be explained by after-nystagmus. He asserts that the theory is untenable because after-nystagmus is a purely local process, for it seems to depend upon the stimulus (in this case, a striped field) and on speed of movement.

Further studies have been made by Roelofs and Van der Bend (105), and Fischer and Kornmüller (37). The chief results gained by Roelofs and Van der Bend were (1) that nystagmus is more readily produced by left to right motion than right to left; (2) that its strength is, in general, inversely proportional to the speed of movement; (3) that the intensity of movement increases in proportion to an increase in the size of the perceptual field; and (4) that the optimal conditions for arousing nystagmus occur when the retina is stimulated by from three to twelve visual outlines per second on each retinal point. Kestenbaum (63) has introduced the genetic method in the study of these phenomena. At the second or third week a certain normal movement of the eye begins. At first the movements are saccadic, but by the third to fifth month they proceed more smoothly. Optokinetic nystagmus has been produced as early as the fifth week, but it does not appear regularly until after the third month. It would appear, then, that these phenomena are related to the development of fixation.

Travis (121) has continued the studies begun with Dodge on the nature of perception of movement during passive oscillation and rotation. Adequate perception of the direction of rotation is found to vary directly with vestibular excitation when the interval between rotations and duration is constant. When acceleration is constant, adequate perception varies inversely with interval and duration. When both acceleration and duration are constant, correct perception varies directly with the interval. Intense stimuli applied to the vestibular system inhibits less intense stimuli but less intense stimuli do not seem to modify a more intense stimulus. Both subjects were

more sensitive to rotation to the right than to the left. The same technique was used in a further study of the problem (122). When ocular pursuit of a slowly oscillating object was superimposed upon vestibular reflexes induced by rotation of the body, the vestibular responses, both subjective and objective, were reinforced. When, however, the pursuit movements were in harmony with vestibular reflexes, the visual cues served to inhibit the vestibular events. Hallucinations of movements were reported frequently during control periods when the body was actually quiescent. Since obscure stimuli may play a part in problems of this kind, Travis implies that there may be some sort of central addition to peripheral excitations. These central events may now predominate over and then subserve the peripheral processes. In a study somewhat related to these, Malassez (77) describes the perceptual functions aroused by angular speed, especially on aviators and deaf mutes. Observed variations in perceptual events led him to suggest that the method might have clinical value.

(iv) *Modes of Response.*—The bodily outcomes of vestibular stimulation have been described frequently in connection with the methods of stimulation; but a few papers deserve special mention. We may begin with special studies of eye movement. De Nó (86) argues that ocular movements are always combinations of lateral, vertical, and rotational movements. This is, of course, by no means new. With characteristic thoroughness the slow phase of optic nystagmus undergoes description by Dodge, Travis and Fox (25). Hemmes (51), Esters (31), and Sorsby (110) describe some of the characteristics of latent nystagmus. Esters emphasizes the relation of latent nystagmus to visual localization and other eye movements. Sorsby reviews the literature in a helpful way.

On the clinical side, Fischer (34) has materially improved diagnostic technique by one of his most elaborate researches. With the aid of several refinements in apparatus, he studied eye movements by the after-image method. Within ranges of head or body inclination from 0° to 40°, rolling of the eyes increases the greatest amount, 5° to 6° being found at 40° inclination. This compensatory rolling has both a transitory and a persistent component, the former depending on the speed of inclination and corresponds to the "slow" component of rotational nystagmus. It vanishes after a few seconds in the inclined position. The other component remains so long as the inclination is maintained and is a persistent position-reflex. Fischer is mainly concerned with this second component. In a subsequent

study, Fischer (**35**) finds that the maximal counter rolling of the eyes is from 4° to 6° when the body is inclined 60° from vertical.

Several papers are devoted to general problems of tonus. Langworthy (**68**) has studied by way of the literature the two components of the "walking reflex." This is a highly adequate review of the facts concerning the control of posture by the central nervous system. A "new" mode of response, attributable possibly to the labyrinth, has been described by Leidler (**71**). It appears that if a person in the erect position places his feet 30 cms. apart, raises the arms to the vertical parallel with the head, and then bends forward with eyes closed, a rotary motion of the head and upper trunk will initiate the feeling that feet are displaced in a diagonal direction. The chances are that these events are related to the phenomena of past-pointing.

Cleminson (**17**) verifies some work done by Tait and McNally (**115**) on the movements of particular muscles in response to surgical insult. The latter worked on frogs, whereas the former used a subject who had become deaf in the left ear and who showed no responses to caloric excitation. Fulton, Liddell and Rioch (**40**) find that one-sided destruction of the vestibular nuclei has a pronounced effect upon the knee jerk. The subject was a cat and the effect of surgical insult was to cause the knee jerk to become spinal in character. The authors conclude "that the vestibular nuclei are essential for the maintenance of decerebrate rigidity, and that they normally exert their influence through control of the inhibitibility of the lower spinal centers." Nishihata (**85**), following an example set by Magnus, studies the posture reflexes of birds. Head position, wing position, and leg and tail postures, in particular, were examined. On the whole, the researches verify the original studies by Magnus. In two papers, Benjamins and Huizinga (**9, 10**) study the general question of vestibular tonus. Pigeons were used and, with the aid of different methods, the tonus of the limbs and neck was studied before and after operation on the labyrinth. The greatest effect was found in the neck muscles. Evidence was found that the labyrinth may regulate wing tonus synergic with the proprioceptors. In the second paper (**10**) parts of the labyrinth were extirpated and an attempt made to discern the functional significance of these various parts. Destruction of the pars superior induced almost the same effects as total extirpation. The papers offer a good example of the way in which partial extirpation may disturb the function of remaining parts.

(v) *Anatomical and Physiological.*—We shall consider the ana-

tomical and physiological features of equilibration in the most summary way possible, partly because so much has been implied in other parts of the review, partly because the literature is so large as to warrant a special review, and partly because not much of the work that has been done is particularly germane to the psychological aspects of equilibration. Controversy still prevails concerning the extent of movement in the otolith and the significance of such movement. Werner (129), in a study of the sacculi of fishes, rejects all grossly mechanical theories. He tends to favor the notion that the otoliths, as a result of their weight, betray differences of pressure in the fluid of the labyrinthine spaces without actually suffering displacement. Huddleston (55) has studied the relation between the saccular otoliths and labyrinthine reflexes in frogs. The reflexes were tested before and after removal of one and of both sets of otoliths. After an observation period of from ten to twenty days the brains of the animals were removed for microscopic examination. Parallel sections of the operated labyrinths showed the extent of labyrinthine injury. No appreciable changes in the labyrinthine reflexes in posture or in the tone of the muscles was found following the complete removal of one or both sets of otoliths. The author inclines, therefore, to the opinion that the saccular otoliths play an insignificant rôle in the mediation of the equilibratory reaction. De Kleyn, de Nó, and Groebbels remain the most persistent students of the anatomy and physiological function of the vestibular structures. De Barenne and de Kleyn (5) study the relation between the growth of eye muscles and equilibratory mechanisms. Cross transplantation, extirpation of all six external eye muscles, and other means were used in correlation with changes in nystagmus. De Nó (88) reports lengthy experimental work on the innervation of the eye muscles of rabbits when the head is rotated in various planes and at variable distances from the axis of rotation. A distinction is drawn between the otolith organs called sluggish receptors and the canals which are called quick receptors. An answer is sought to such questions as the relation between the intensity of the vestibular reflex and the cosine of the angle between the plane of rotation and the plane of the stimulated canal, the amount of current induced in a canal when rotation occurs in some other plane, how impulses from different canals are integrated in the central nervous system, and the like. This appears to be one of the best pieces of work de Nó has done. Groebbels (46) compares one set of results with a set that had already been reported and which could be used as a control. He argues that lesions in the

labyrinthine structure show that both the labyrinth and cerebellum control and integrate the tonus of the neck and wings. Blohmke (14), in a well illustrated article, describes the inner ears of several species of amphibia, reptiles, birds, and mammals. He finds that vertebrate sense organs in the labyrinth may be divided into two groups, the one group (the three cristae ampullares, the macula utriculi, the macula lagenae, the macula sacculi, and the papilla neglecta) reacting to change of position of the organism and the other group (the papilla amphibiorum, the papilla basilaris, and the macula sacculi) reacting when the labyrinth is not in motion. The differences between various vertebrate balance mechanisms are described and the functions of the various parts tentatively assigned. De Burlet (12) has given a richly illustrated description of the labyrinth of petromyzon. Comparisons are drawn between his own and other descriptions and some additional observations are made such as the flow of liquid in the labyrinth, the slight right and left movements during swimming, and the like. Disorientation was induced by extirpating the labyrinths. An equally good description of the vestibular receptors of the lamprey is made by Versteegh (126). Like petromyzon, lamprey appears to have only two semicircular canals, the horizontal canal being missing. The inner side of the labyrinth is lined with ciliated epithelium. Furthermore, the endolymph is shown to be in constant motion. These are only a few of the papers on anatomy and physiology. Much work, some of which has been suggested above, on the central connections of the vestibular apparatus, falls properly to a special review.

(vi) *Clinical and Pathological.*—We shall make brief mention only of clinical and pathological material. French (39) has found material for psychoanalytic studies of ear infection of long standing. Evidence for hereditary factors behind the appearance of nystagmus has been gathered by Knighton (67), Cadwalader (15), Kitahara (64) and Steggerda (112). Steggerda suggests Mendelian inheritance. Menière's disease receives a general summary by Thornval (118). The bibliography is exceptionally useful. Mygind (83), and Mygind and Dederding (84), give clinical pictures of the Menière syndrome, including descriptions of the principal types of nystagmus. Helsmoortel (50) and Portmann, Despons and Retrouvey (101) describe the relation between encephalitis and residuary lesions of the vestibular tracts. Walter (128) finds that long continued rotation of rabbits causes a permanent compensatory twisting of the head. Cords (20) describes nystagmus movement incident upon skull

injury. Examples of diagnostic technique and results are to be found in Thomas (117), de Kleyn and Schenk (65), Barr (7), Portmann and Mailho (102), and Vogel (127). Vogel's study appears to be most competent. Ohm (98) has made a special study of nystagmus in albinos, who comprise 7.8 per cent of all cases of non-occupational nystagmus. Horizontal movement is found most frequently. Voluntary nystagmus, related presumably to head congestion, has been studied by Bartels (8). Crowe (22) describes the anatomic changes which follow cerebellopontile and brain stem tumors.

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Intuitive Thought: I. Beyond Discoursive Thought; II. Invention and Verification.

These two volumes set forth and clarify the philosophy of Bergson. The main chapter is chapter 4 of the first volume, in which the author gives a careful description of the act of intuition and its different kinds. It must be said that he has succeeded in clearing up, although in a more literary than scientific way, the whole philosophy of Bergson, and especially the concept of intuition. He has succeeded in proving that before logic and dialectic can go to work there has to be given something intuitively present to the mind. It is to be hoped that future work on Bergsonian philosophy will clear up still further the psychology of intuition and make it more easily understood for everybody. These two volumes should be read by anyone interested in the problem of intuition.

E. VON DOMARUS.

Yale University.

NELSON, LOUISE A. *Variations in Development and Motor Control in Goiterous and Non-Goiterous Adolescent Girls.* Baltimore: Warwick and York, Inc., 1929, pp. 193.

The present work is particularly welcome because of "the vast and voluminous literature on the thyroid apparatus reveals little that is definite and conclusive. One is impressed by the large amount of generalization, speculation, and assumption; the very small amount of conclusive experimental proof, and the rich possibilities for further researches in this field."

There was studied 149 goiterous, adolescent girls ranging in age from twelve to twenty years and a group of 51 non-goiterous girls, ranging in age from twelve to twenty-one years of age. A comparative study of these two groups was made of Physical Measurements and Motor Control (Coördination, Steadiness, etc.).

Dr. Nelson reports her findings sanely, commendably free of alarmist propaganda. The problem of thyrotoxicosis is a pertinent one and the individual suffering a thyroid dysfunction labors under a handicap. There is suggested the need for intensive psychological

study of behavior deviations correlating with these cases of disturbed metabolism.

Further, the individual should be made cognizant of his or her particular type of nervous mechanism so that the necessary industrial or educational adaptation can be effected. "They should learn that many of their symptoms and reactions, such as suspicion, irritability, etc., have an organic basis and that they must learn how to react to it." This is an orientation worthy of the best mental hygienist.

An excellent historical résumé of the question of thyroid function is presented in the first chapter. The book is well written, the experimentation well performed, and Doctor Nelson's thesis well defended.

YALE S. NATHANSON.

University of Pennsylvania.

AVELING, FRANCIS. *The Psychological Approach to Reality.* London: University of London Press, Ltd., 1929, ix+251.

F. A. distinguishes different "types" of reality, *i.e.*, the world of empirical reality, the world of ideal reality, the reality of causation, the reality of final causes and the transcendental reality. The author maintains that the problem of Truth and Reality is a theoretical problem rather than a practical one; "since, whether we solve it to our satisfaction or not, we somehow manage to get on with our life and living, taking many things for granted which we cannot, perhaps, understand or explain." To solve the problem in question, A. employs the Principles of Neogenesis, as formulated by Spearman, and uses the results of the investigations of the Würzburg and Louvain Schools. The problem is "envisaged from the point of view of solipsism, from the very nature of the case." His conclusion is: "the sole available criterion of truth is evidence and the insight we have of it. It is a criterion wholly cognitive; intrinsic, immediate, and objective. But, since the spurious evidence of mental products due to retentivity is possible of occurrence, prudence will suggest suspense of judgment until real and objective evidence is manifest. . . . In many instances there would seem to be no certain psychological way of distinguishing between true and spurious evidence; and in those instances he is truly wise who gives to his assent no greater value than the evidence allows, who weighs one evidence for or against another, and suspends his judgment until insight is complete. . . ."

E. VON DOMARUS.

Yale University.

COMMUNICATION

MILNER PARK, JOHANNESBURG, 22nd February, 1932

The Editor, PSYCHOLOGICAL BULLETIN:

DEAR SIR—During the night before Christmas Eve, a disastrous fire destroyed a large portion of the Library of the University of the Witwatersrand, which, pending the erection of a permanent Library building, had been housed in a temporary structure.

Among the books destroyed by the blaze were many philosophical and psychological works by American scholars. Owing to my own connection with Harvard and other American university institutions and my many personal friendships with American thinkers, the works of American philosophers and psychologists were probably better known to, and more extensively used by, my students than by those of most other British universities. Hence the loss of so many American works is particularly serious.

Unfortunately, the loss is only in small part covered by insurance; and it will be readily understood that, in the present world-wide depression, it is difficult to raise the sum required for the repurchase of all the books which have been lost.

In these circumstances, I venture to appeal to all American philosophers and psychologists, and especially to my old colleagues and friends, for the gift of author's copies of their own writings or duplicates from their libraries, to help me build up again, as soon as possible, a working library for my students.

Every such gift—addressed to The Librarian, University of the Witwatersrand, Johannesburg, South Africa—will be gratefully acknowledged, and the names of the donors, together with the occasion of the gift, will be recorded in the volumes themselves.

Yours truly,

R. F. ALFRED HOERNLÉ,
Head of the Department of Philosophy.

CORRECTION

I hasten to correct a completely false statement made in the History of the American Psychological Association (PSYCHOL. BULL., 1932, 29, page 51). In discussing the report of the Committee on Certification Policy (of Consulting Psychologists) made in 1927, I say: "This committee then reported that they believed the certification of Consulting Psychologists was not practicable for the Association and that it be discontinued. The Council recommended that the report be accepted and the committee discharged and that the by-laws be changed in accordance with this report so as to eliminate certification entirely."

Professor Margaret F. Washburn, who was Chairman of the Committee on Certification Policy, has kindly pointed out the error of this statement. As a matter of fact her committee approached the matter from the democratic point of view and with a thoroughly experimental method. This was accomplished by a mail vote of the members of the Association on these matters and the Committee's report was in favor of continuing certification which was in accordance with the very clear result of the mail vote. The Council of Directors, in spite of the mail vote and the report of the Committee on Certification Policy, framed a motion to change the by-laws so that certification would be eliminated. After considerable discussion and after several attempts to save certification, the members voting at the meeting completely reversed the mail vote and adopted the recommendations of the Council of Directors rather than those of the Committee on Certification Policy.

Unfortunately the minutes of this meeting are not clear on this point—for which there is no excuse inasmuch as they are my own.

SAMUEL W. FERNBERGER.

University of Pennsylvania.

NOTES AND NEWS

ACCORDING to *Science:* On the occasion of the dedication of the Graduate Education Building of the University of Chicago, the honorary degree of doctor of science was conferred on Dr. Edward Lee Thorndike, professor of education and director of the division of psychology of the Institute of Educational Research of Teachers College, Columbia University.

DR. ARTHUR O. LOVEJOY, professor of philosophy at the Johns Hopkins University, has been appointed the second incumbent of the William James lectureship at Harvard University for the first half of next year. Dr. John Dewey, professor of philosophy emeritus at Columbia University, was last year the first William James lecturer under the foundation for psychology provided with nearly $800,000 by the will of Edgar Pierce, formerly instructor in psychology at Harvard.

DR. COLEMAN R. GRIFFITH, associate professor of educational psychology at the University of Illinois, addressed the St. Louis University Sigma Xi Club on March 14 on "Some Studies on Exercise and Fatigue."

DR. W. V. BINGHAM on March 18 delivered an Aldred Lecture at the Massachusetts Institute of Technology, the subject being "Adventures in Industrial Psychology."

PROFESSOR A. A. GRUNBAUM died at Amsterdam on the tenth of January, at the age of forty-six.